

Nutritional Biochemistry



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The history of biochemistry actually started with nutrition. The first biochemists explored vitamins and how they worked, and what kind of deficiencies you'd see if someone lacked those particular nutrients. Basically, they observed certain disease states, like pellegra or rickets and were able to link to lack of certain foods. Chemists would then isolate various chemicals from the food to learn what the missing ingredient was. Think about the Limey sailors who discovered citrus fruits prevented scurvy. Only years later when technology evolved could biochemists discover that it was vitamin C in the limes that reversed the disease. Scientists felt that if we understood the chemistry of the body and what wasn't working, we could fix anything. In other words, it was better living through chemistry, just plug in the missing or 'broken' molecule and illnesses would be fixed.

In the 1960s, biochemistry was very much a reductionist discipline. Decades later, the whole person and family become part of the "biochemical equation", followed by stress, the mind and body.

Rather than seeing biochemistry as just another piece of academic information, we invite you to enjoy the visit into the deepest molecules of life, your life. Every physical part of us is chemical and by understanding just a bit of this vast wondrous molecular universe you may better appreciate how

the vitality and health of your body depends on what its being fed.

The Basics: Meet your Molecules and Cells

Language of Biochemistry – Structure and Function

Life is organized in levels starting with the tiniest atom, element, and molecule, from single cell up to our 100 trillion-celled human. First we start with the smallest structures to understand what we're made of and how we can tend to our proper nourishment. At every level there is a hierarchy like the Russian dolls, one fits into another.

Each part has precise structure that dictates its functions. We'll first look at the basics and gradually see our body in greater and greater complexity.

KEY CONCEPTS: *life, atom, element, molecule, bonds, ion, cell, structure, and function*

Life's Atoms, Elements, and Molecules

Imagine biting into a crisp juicy apple. Your mouth and body are flooded with molecules and the basic elements of life. Everything physical, whether an apple, a glass of water, or steam rising from the tea kettle, is made of atoms.



Nutritional Biochemistry—CONTINUED

Atoms

All atoms have the same basic structure. The most familiar physical model of the atom is the solar system. The center core of the atom (nucleus) is surrounded by tiny orbiting particles (electrons.) The core contains tightly packed *protons* (positive-ly-charged) and *neutrons* (no electrical charge.) Orbiting around the center, at extremely high speeds, are negatively-charged *electrons*. The only difference between one kind of atom and another is the number of electrons, neutrons and protons that make it up. Atoms are electrically neutral as they have an equal number of positively and negatively charged particles.

In reality, an atom is a field of energy, or actually fields of vibrating energy.

The simplest atom is hydrogen which consists of one proton in the nucleus with one electron orbiting around. An atom that loses or gains an electron becomes electrically charged and is now called an **ION**.

You can think of atoms as letters (*unlimited potential*), elements are words (*defined meaning and properties*), and molecules are sentences (*specific directive usefulness*.)

Elements

An element is the smallest physical unit of an atom that retains distinctly different properties.

An *element* is made up of one kind of atom. Most elements are solid and most are metals. So far, 113 elements have been discovered. Examples: oxygen, nitrogen, and lead. We don't eat elements though elemental sulfur is sometimes used in the garden or a winery. We breathe in elemental oxygen and nitrogen.

Elemental oxygen is made up of two atoms of oxygen; this is also molecular oxygen. All this nomenclature is confusing yet its understanding will help you grasp a useful overview of the chemistry of food and metabolism.

Each element is represented by a:

- Chemical symbol
- Atomic number
- Atomic mass

Oxygen

- Chemical symbol is **O**
- Atomic number is **8**
(8 protons)
- Atomic mass is **16**
(8 protons + 8 neutrons)

Chemical Symbol is an abbreviation of its chemical name

Atomic Number is the number of positively charged protons. The number of neutrons and electrons is the same number as the number of protons.

Atomic Mass is the "weight" or total of the protons plus neutrons, basically it's the mass of the core nucleus.

What chemical symbols do you already know? Hydrogen? Carbon? Chlorine?

The number of electrons equals the number of protons in an atom; however, since an electron is so small it's not considered in the mass of an atom. Basically, the electrons are the particles in an element that move and determine the chemical properties.

Russian scientist Dmitri Mendeleev discovered an order to the elements that he called families which share similar properties. He put these families into a grid, *The Periodic Table of Elements*. Each column of elements share some common properties. The elements that the human body can use are those with lower molecular weights, basically those on the first four rows of the Periodic Table. Remember the only difference between each of the elements is the number of protons, electrons and neutrons, which are invisible subatomic particles.

Nutritional Biochemistry—CONTINUED

Elements of Life

Carbon (C), Oxygen (O), Hydrogen (H), and Nitrogen (N) are the primary elemental ingredients for life. Life on the planet earth is carbon-based. Some scientists speculate that life on other planets could be silicon-based and not use carbon. Plants use a lot of silicon in their stems, and glass and sand are mostly silicon (aka silica).

What is your body made of?

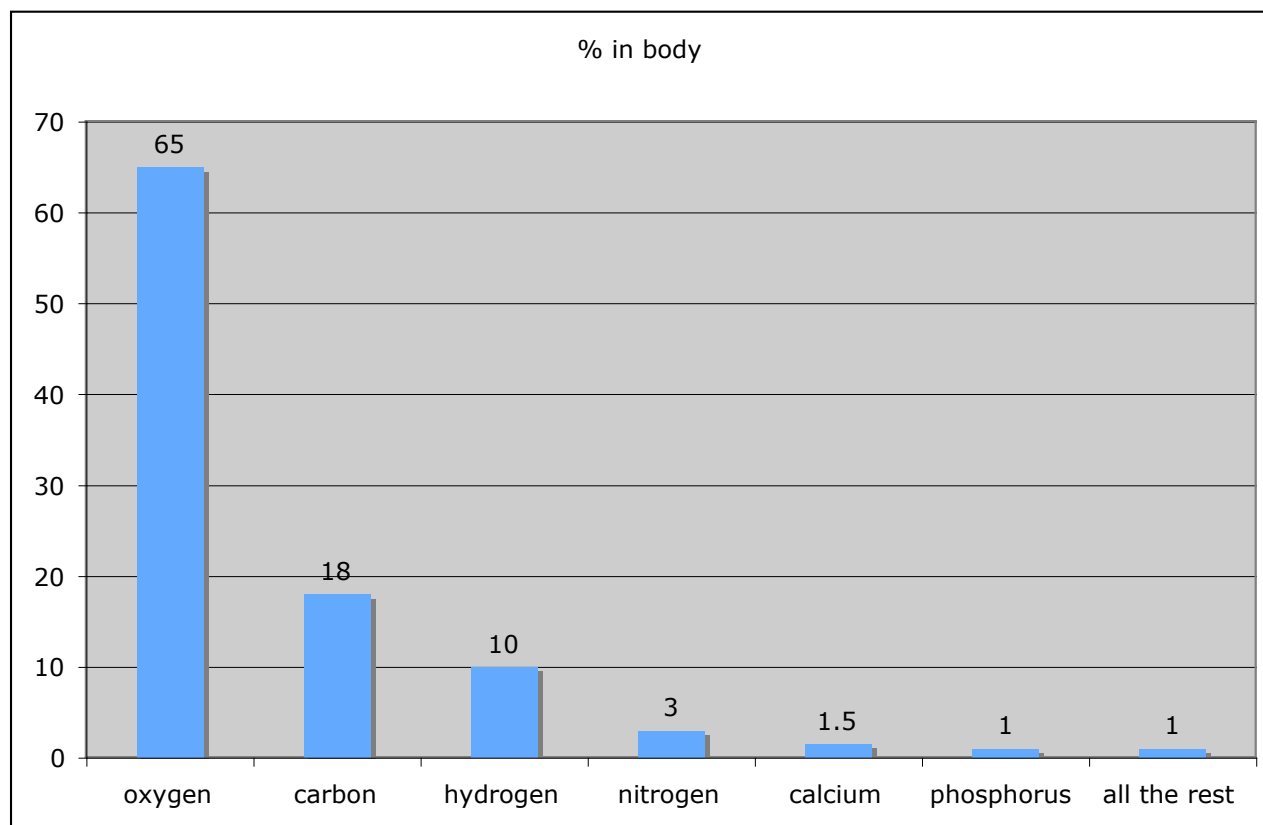
The elemental ingredients of the human body are shown in the following proportions, in the graph below.

All the Rest

Another 1% of the body's elemental makeup includes all of these:

- Sulfur (S)
- Iron (Fe)
- Sodium (Na)
- Zinc (Zn)
- Chlorine (Cl)
- Magnesium (Mg)
- Silicon (Si)
- Potassium (K)
- Plus the trace elements like chromium (Cr) and molybdenum (Mo)

The carbon we obtain comes from plant food or meat, oxygen comes from the air, and water. The mineral elements like sulfur, calcium, and magnesium come from the soil which ultimately gets into plant and animal food. Our bodies cannot make any of the mineral elements. They must come from food or supplements.



Nutritional Biochemistry—CONTINUED

Molecules: The Ultimate Bonding Embrace

When we eat something our body revamps the atoms and molecules into molecules we need to survive. Molecules are made of one or more atoms held together by chemical bonds. To form new molecules, molecules either share their electrons or give some away. What our bodies need for energy, growth, protection, and repair are molecules.

The old saying that opposites attract is certainly true at the molecular level. Charged particles are always ready for a little bonding.

Bonding Relationships

Shared Electrons (covalent bonds) — Electrically neutral, tight, cohesive relationships

COVALENT BONDS are formed when two atoms share a pair of electrons between them. Most **organic compounds** are built through covalent bonding. For example, covalent bonds are found in carbon dioxide, water, and glucose.

Covalent bonds can be single (C–C), double (C=C) or triple (C≡C) depending on how many pairs of electrons are shared. Single bonds means one pair of electrons is shared. They are part of every organic molecule. Double bonds share two pairs of electrons, and are found in unsaturated fatty acids and aromatic amino acids like tyrosine. Polyunsaturated fatty acids have several double bonds. Very few chemicals in our bodies have triple bonds.

Electrons Given Away (ionic) — Magnetic, electrically charged

IONIC bonds are formed when electrons transfer from one atom to another. Table salt (sodium chloride) is a perfect example. Sodium is a positively charged ion (*cation*) and chloride, negatively

charged (*anion*.) Most *inorganic compounds*, metals and minerals like calcium, selenium, and potassium form ionic bonds. Ionic bonds are easily broken by water. Ionic compounds can separate in water and transmit electricity. These are then called *electrolytes*.

Examples:

2 atoms Hydrogen (H) + 1 of oxygen (O) partner to create water (H₂O) by sharing electrons. (*actual chemistry is one molecule of hydrogen (H₂) and one oxygen (O₂).*) Sodium (Na) meets chlorine (Cl) and gives it an electron to produce the very salty sodium chloride (NaCl) with sodium being + charged (Na⁺), chloride negative (Cl[–]).

TASTE TIP

The taste of salty or sour is because of the ions sodium (Na⁺) for salty, hydrogen (H⁺) for sour. They touch onto the taste receptors and immediately enter inside the cells through ion channels or pores. Though table salt is more than 95% sodium chloride, depending on its source, it can contain other minerals depending on its source and how crystalized. Iodized table salt has been treated with potassium iodide and may also include aluminum, calcium, magnesium carbonate and silicon dioxide. The latter prevents caking.

The taste of salty tells the body this is an essential mineral source. The taste of sweet gives the message this is an energy source and usually a sugar. Sour says this is an acid, unripe, fermented or spoiled. Bitter tastes warn of danger and most often are from nitrogen-containing alkaloids. The 5th taste of umami or savory tells the brain that the food is a source of nitrogen, usually an amino acid or protein. Recently a 6th taste receptor for fat has been proposed. In the wisdom of the body, the universal pleasurable tastes are savory and sweet, essentials for survival.

Nutritional Biochemistry—CONTINUED

Naming Molecules

The name of a molecule gives us clues to its chemistry. For instance, a molecular name that ends in *-ol* tells us that the elements have combined to make an alcohol. Names that end in *-ate*, such as sulfate tells us its a salt and electrically charged. Examples include sodium bicarbonate (baking soda) NaHCO_3 , and monosodium glutamate (MSG.)

Water: Essential Molecule For Life

Water is the smallest and simplest of our food molecules yet is the basis for all life. Water is a major molecule of our bodies comprising anywhere from 60–75% depending on the specific tissue. Just think of all the fluids that are part of us — blood, saliva, and urine.

Water is the only liquid essential for life; it is a major component of our blood, cells, and the spaces between cells. Water's unique structure helps organize molecules into specific relationships.

The next time you sip water, consider that it is unlike any other molecule. It can dissolve many of the molecules we need, hence is called the universal solvent for other charged, polar, or water loving (hydrophilic) molecules. It stabilizes temperature. Cells owe their shape and rigidity partially to water. Most essential molecules of life dissolve and transport easily in water.

The Body's Water Use: A Simple Overview

In our lifetime we will likely consume the equivalent of more than two 9,000 gallon tanker trucks of water. And we lose almost that much as well. There's a constant loss of water through the skin, lungs, urine and feces, about 2.5 quarts a day. Sweating alone in extreme heat or workouts can

increase the loss to 3 or 4 quarts or liters. There's careful regulation of our fluid levels particularly in blood volume which must be at least 3.5 liters. Our cells make a small amount of water each day, about 0.2 liter (200 ml) yet much less than we need. Therefore taking in adequate amounts of pure water or liquids is essential for cellular and body health.

Recommended daily fluid intake is about 2.5 quarts of water that can come from liquid or food. Whether it comes from an orange, an apple or a piece of cheese, your body can pull out water from everything you consume.

Some metric conversions:

- 28.5 grams = one ounce
- 1 liter = 1000ml and is about 1 quart
- 454 grams (g) = 1 pound
- 1 kilogram (kg) = 2.2 pounds

Amount of water in some foods:

- 1 whole cooked egg weighs about 50g has 37g water. (74%)
- 1 celery stalk (40g) has 38g (95%)
- a piece of cheddar cheese, 1 oz. has 10g water (35%)
- 1 oz. almonds (24 nuts) has 1.4g (~5%)

(2009 www.realage.com; www.nal.usda.gov)

If we don't get enough water we run into dangers — toxicity, fatigue and constipation. Water makes up the bulk of the blood circulating in your body. And blood moves waste and nutrients around. Therefore, the more we limit our fluid intake, the more concentrated the waste becomes, the less available nutrients. Over time this can account for a lot of fatigue and exhaustion. So for yourself and your clients, when fatigue is a major issue, ask about fluid intake.

Nutritional Biochemistry—CONTINUED

Acids, Bases and pH

Water has very special properties as mentioned earlier. It also dissociates (separates) into its hydrogen ions. Positively-charged hydrogen ions, called protons, have dramatic effects on other molecules. Molecules that release protons (H⁺) are acids. However, water is not considered an acid since it releases equal portions of protons (H⁺) and negatively charged hydroxyl ions (-OH⁻); they balance each other out. Proton concentration is so significant we have a specialized taste sensation to estimate it: *sourness*. The word acid comes from Latin *acere* for sour taste. Most acids taste sour.

We also have a special measurement — pH. A measurement of the degree of acidity (or lack of it) is determined by pH. The pH scale measures the relative concentration of protons and ranges from 0-14. Neutral pH is 7, acids are below 7; substances are considered alkaline or basic when pH is above 7. The following pH scale shows the range of proton activity of common household solutions, food and body fluids. Gastric fluid is 1.3-3, lemon juice is 2.1, and blood is 7.4 while urine and saliva are normally around 6.4.

The lower the number the more acidic; the higher the pH, the more alkaline. Some whole foods may measure acid pH; however, after digestion they deliver more alkaline products.

TASTE TIPS

The more free hydrogen (H⁺) in solution, the more *sour* the taste. We only taste things that can be dissolved in our saliva — water soluble.

Basics of Life: Our Cells

Water is the molecule that allows life to happen and the human body contains thousands of different molecules, some we can make in our cells, like DNA and protein; others we must obtain from our food like vitamins and minerals.

We are chemical wonders. Molecules organize into communities that form all the structures necessary for life. Understanding how our cells work gives us a greater knowledge of the role good nutrition plays at the micro level.

pH LEVEL	NUMBER OF PROTONS	SUBSTANCE
0	10,000,000	Battery acid
1	1,000,000	Stomach hydrochloric acid
2	100,000	Gastric acid, lemon, vinegar
3	10,000	Grapefruit or orange juice, soda
4	1,000	Tomato juice, acid rain
5	100	Soft drinking water, coffee
6	10	Urine, saliva, milk
7.0	0	Distilled water
7.4		Human blood
8	0.1	Sea water
9	0.01	Baking soda, toothpaste
10	0.001	Milk of Magnesia, Great Salt Lake
11	0.0001	Ammonia solution
12	0.00001	Soapy water
13	0.000001	Bleach, oven cleaner
14	0.0000001	Liquid drain cleaner, lye

Nutritional Biochemistry—CONTINUED

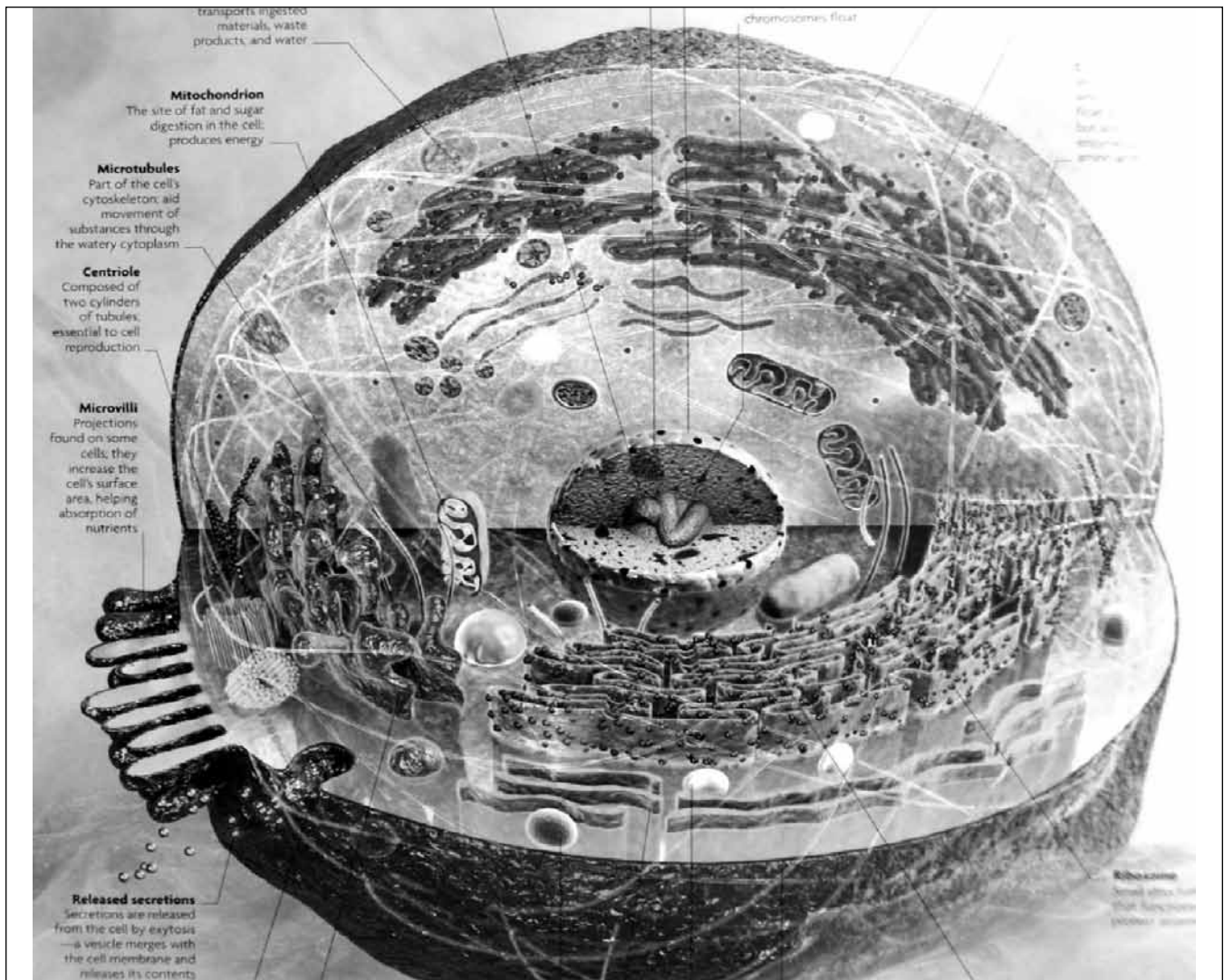
Functions Essential to Life

Believe it or not, the definition of life is not agreed upon, yet does include the following requirements:

- Ability to grow and reproduce (making more of themselves)
- Find and use food — metabolism (transform food to energy and raw materials)
- Reproduction, maintain structural integrity and repair
- Genetic intelligence
- Discard waste
- Sense and respond to stimuli, communication
- Adapt to the environment
- Movement

Smallest Unit of Life is the Cell

- A cell is the smallest functioning unit of a living organism and carries out the basic functions of life including reproduction. Most scientists do not consider viruses alive since they need the machinery of a living cell to reproduce.
- The size and health of a cell is influenced or limited by its genes, the nutrients it can take in, and how well it gets rid of its wastes.
- Cells exchange molecules with its environment through diffusion, active transport (requires energy), ingestion, and cellular 'eating' (pinocytosis and phagocytosis.)
- Everything we need for physical survival is maintained by the life of our cells. The hu-



Nutritional Biochemistry—CONTINUED

man body is composed of about 10 trillion cells originating from one fertilized egg cell. During embryonic development cells specialize and take on unique features and responsibilities such as blood cells and liver cells, skin and muscle. Though different in specialized tasks they also share basic features and functions.

Architecture and Components of Our Cells

Life needs a container! Molecules merge to form a container with a resilient flexible surface that protects, defends and defines the cell self. This is called the plasma membrane.

Cell Membranes: Creating the Container For Life

Functions of the Cell Membrane

In animal cells, the outside surface is called the plasma or cell membrane, not cell wall. Plant cells have the more rigid cell walls.

Cell membranes:

- Hold things in, let things out, and protect
- Insulate forming boundaries and provide identity
- Provide discriminating flexible, semi-permeable barriers

The plasma membrane has a role in cell-cell recognition, maintenance of cell shape, and cell locomotion. The initiating site of action for many hormones and metabolic regulators is on the plasma membrane.

The composition of our cell membranes is greatly influenced by diet. The primary components are fats, proteins and cholesterol. The physical properties of the fats control the shape, function and fluidity of the membrane.

The composition may vary in terms of specific fats

and proteins, depending upon cell function and location.

A cell membrane is made up of 2 layers of fats that have the lipid parts facing towards each other and the polar charged portion of the molecule facing the watery internal and external environments of the cell. Lipids are fat-loving and water-fearing (hydrophobic) molecules. Fats are lipids and are insoluble in water. Phospholipids are the form of fats in the cell membrane.

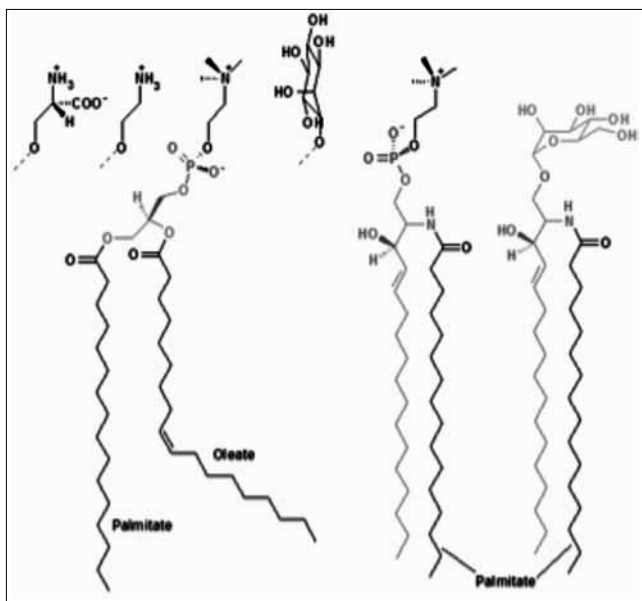
The 3 major fats in the membrane are fatty acid, cholesterol, and phosphoglycerides (phospholipids.) Fatty acids are chains of carbon atoms with an acid group at one end and a methyl group at the other, and can be saturated, trans or unsaturated. Some fatty acids are linoleic, linolenic, and stearic.

An acid group, also called carboxylic group has a formula of COOH . The part of the molecule with an acid group is water soluble. A methyl group has a formula of CH_3 and that portion is lipid soluble. A hydrocarbon is a combination of methyl groups with CH in between which shows why it is NOT soluble in water. $\text{H}_3\text{C}-\text{CH}_2-\text{CH}_2-\text{CH}_3$

The shape of the fatty acids regulates membrane function and permeability. Both can be altered by fatty acid composition of the diet. Saturated and *trans* fats are straight chains which make the membrane more rigid, less flexible. On the other hand, *cis* bonds, the natural double bonds in fats prevent tight packing and allow for space in the membranes. *Cis* bonds have kinks and allow flexibility in the membrane. These spaces can move around within the membrane and can be filled with water and small ions. Phospholipids contain fatty acids.

In the diagram of fatty acids below, palmitate is saturated and you can see that it is a long straight molecule. Oleic (oleate) is unsaturated and at the double bond the molecule bends. In the cell membrane this creates space for nutrients to come into the cell.

Nutritional Biochemistry—CONTINUED



Cholesterol, the 3rd major lipid in membranes, is a compact rigid hydrophobic molecule constructed from 4 fused rings. It is a steroid structure. Membranes exhibit the greatest variation in percent composition because the amount of cholesterol is affected by the nutritional state of the animal. Cholesterol content influences how flexible the cell membrane is. Cholesterol, steroid hormones we make or drugs we take, like cortisol, hydrocortisone, or prednisone, change the flexibility of the membrane and how information is transmitted.

Dietary Fats and Cell Function

The healthy function of our cells depends on the flexibility of the cell membranes which in turn is influenced by the quality of fats in it — too much trans or saturated fat make the membranes less flexible. Cholesterol also influences this by making part of the membrane too fluid and other parts less so. We use both saturated fats and cholesterol in our diet; and our cells can make these. A current theory is that trans fats, saturated fats and cholesterol make the cell membranes more rigid. Fluidity influences how well nutrients can get into the cell, how the receptors respond to information and how well the immune cells are able to eliminate pathogens.

Protein Structures in Cell Membranes

In addition to lipids, proteins are the other major component of all plasma membranes. Proteins have definite orientation within and across the membrane. Most have parts that are made of hydrophobic (water-hating) amino acids which interact with the lipids stabilizing the protein-lipid complex of the membrane. Hydrophobic amino acids include valine and leucine. Membranes also contain hydrophilic amino acids that protrude into the outside of the cell and its interior. Water-loving amino acids include glutamic acid and glycine among many others. A protein contains a combination of essential and non-essential amino acids and can be from 50 amino acids long to hundreds in the chain.

Membrane Protein Roles:

- Movement of molecules across the membrane into the cell — transporters
- Structural integrity of cell
- Enzymes
- Receptors, information receivers, recognition
- Identity, markers of identity, antigens

Cell membranes are affected by diet and can be damaged by the internal environment of the body from oxidants and free radicals, excess cholesterol, and trans fats. **Wherever there's a high concentration of fats, especially unsaturated fats, there's a risk of oxidation and free radical damage.** Composition of the membrane will affect enzyme activity, immune system phagocytosis (microbial ingestion), cell growth, and receptor activity (transmission of information.)

The Cytoskeleton — Cellular Muscle and Intelligence

The diagram at the top of the following page shows the membrane with the cytoskeleton connecting to it. The diagram below it illustrates how the cytoskeleton connects every part of the cell. The cytoskeleton is probably the most complex and

Nutritional Biochemistry—CONTINUED

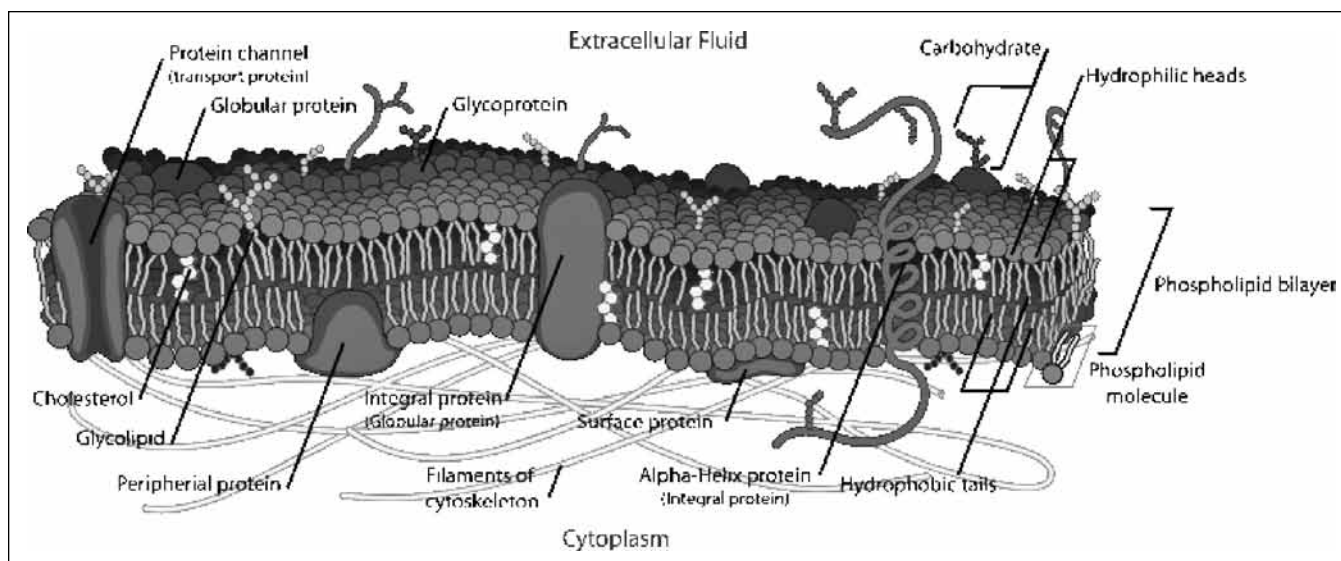


Image of microtubular matrix from *Scientific American* Jan. 1998 *The Architecture of Life* by Donald Ingber, M.D.

least understood part of the cell. Its made of protein structures shaped like tubes and strands in a variety of sizes — microfilaments, intermediate filaments and microtubules. It is the underlying matrix of the cell straddling from the cell membrane throughout the cytoplasm of the cell. The cytoplasm is the watery gel-like material that fills the inside of the cell. Microfilaments are made of contractile proteins actin and myosin. Microtubules, larger in size, function as "tracks" to move along organelles and molecules made by the cells.

Functions of the Cytoskeleton:

- Structural scaffolding or matrix of the cell
- Transport intracellular nutrients
- Movement and cell shape

- Regulate cell growth, mitosis, death, and genetic signals
- Possibly cellular decision-making

Some scientists believe that the microtubules of the cytoskeleton are the seat of consciousness with the ability to sense other cells.

Cell shape, stability, integrity, movement and growth are managed by cellular tension, pulling and pushing on the cables of the cell.

Mitochondria: Energy Banks

Mitochondria are the sites of cellular respiration and contain enzymes to convert food into usable energy. Carbohydrate sources and the breath

Nutritional Biochemistry—CONTINUED

(oxygen) find their way into the mitochondria to be transformed into cellular energy called ATP, adenosine triphosphate.

All intracellular organelles, like the mitochondria and nucleus are surrounded by their own membrane. The mitochondria has distinctly different lipid composition (cardiolipin — diphosphatidylglycerol) than the plasma membrane. This lipid is also found in bacteria!

Mitochondria have their own DNA and genes that are unique structures inherited primarily from the mothers (and the past.) Mitochondria possess the machinery to manufacture their own genetic material and necessary proteins for their specific functions. They replicate their DNA and divide mainly in response to the energy needs of the cell. Cells with the largest energy needs, like muscle, have the most number of mitochondria, can be up to 1000 per cell!

Structure

Consists of two membranes — an outer one permeable to most small molecules and the inner one that doesn't allow molecules to readily pass through it. The outer membrane is about equal amounts of protein and lipid. This inner mem-

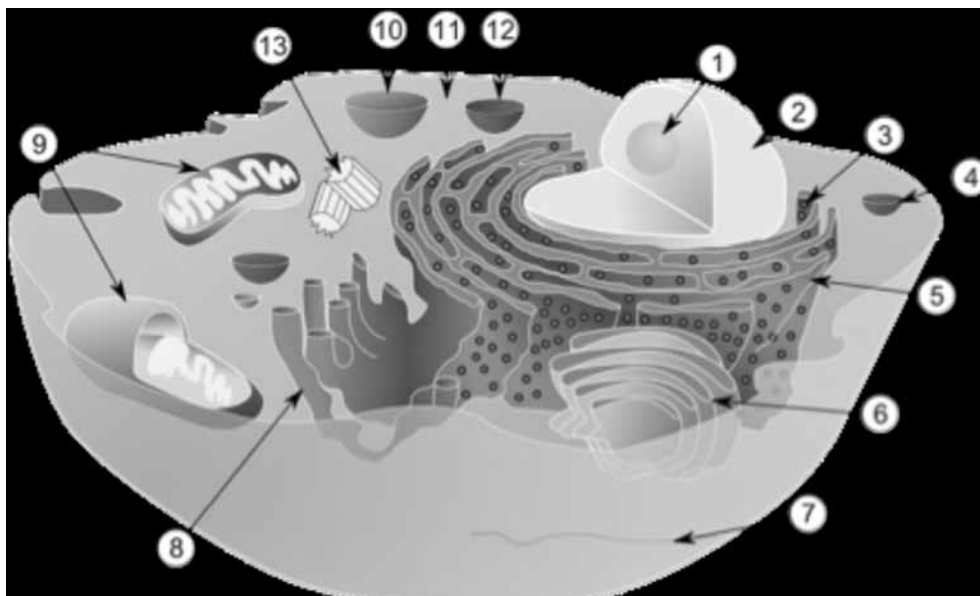
brane, primarily protein, is folded into crypts or cristae containing all the enzymes of the Krebs cycle, fatty acid oxidation and ATP production.

Functions

Aerobic energy produced by mitochondria depends on the essential ingredients transported into the mitochondria. Carbohydrate products enter in via acetyl CoA. Fatty acids and pyruvate require carnitine to transport them into this space which also transports mitochondrial waste out into the cytoplasm.

When proteins (amino acids), lipids or carbohydrates are oxidized, energy is released and can be coupled with chemical reactants which repackage the energy into ATP.

Cell health is compromised by oxidative stress, nutrient depletion, oxygen levels, mitochondrial DNA mutations. And the mitochondria themselves can be damaged by their own physiology if the free electrons they transfer get "loose." Nutrient requirements for mitochondrial health includes electron quenchers (antioxidants) alpha lipoic acid, CoQ10, and glutathione (GSH) plus glucose, oxygen, B vitamins, magnesium, and copper.



#2 nucleus

#5 and 6 where protein synthesis and packaging takes place

#7 cell membrane

#9 mitochondria

#13 microtubules in form of centrioles

Image from *Wikipedia*, the free encyclopedia

Nutritional Biochemistry—CONTINUED

Mitochondrial dysfunction is considered to be part of many neurological and muscle diseases including Parkinson's, fibromyalgia and chronic fatigue syndrome.

Your cells do what YOU do to survive — they breathe, move, eat, get rid of waste and transform food into ingredients you need.

How We Make Energy: Energy Management

Key Concepts:

- What is energy?
- How is it converted from our food into cells?
- What helps the process, what slows it down?
- Without energy, there is no life!

In this section we discuss how our food becomes energy for our cells, what the basic structure of carbohydrates is, and how we can use mind-body lifestyle strategies along with diet to manage our energy levels. We will explore both nutritional pathways and personal strategies for sustaining energy. In terms of food our emphasis will be on carbohydrates since they are the primary chemical resource for making energy. Fats and proteins are back-up sources. The essential function of carbohydrates in humans is for energy storage. Carbohydrates also have secondary specialized functions that include fine-tuning cell receptors and membrane identity markers.

Carbohydrate Basics (CHO) $C_6H_{12}O_6$

Carbohydrates are so named because their molecular structure consists of ratios of one carbon and one water or H_2O . Carbohydrates (sugars) are the unique gift from plants. In plants they are both energy storage and structural support, like the long stalks and stems.

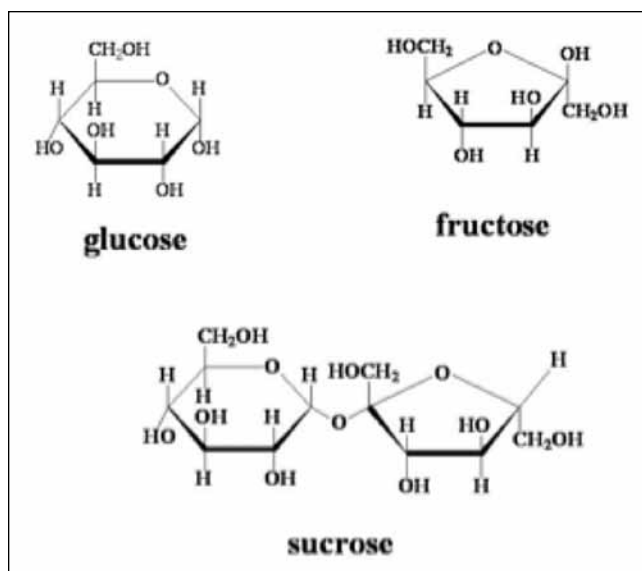
The most common simple sugars are constructed from 5 or 6 carbons. The 6-carbon sugars — glucose, fructose, galactose, mannose — can ultimately be used for energy; 5-carbon sugars ribose and deoxyribose, cannot. The 5-carbon sugars are most important as part of the backbone of our genetic materials — DNA and RNA. Ribose is part of the ATP molecule but has no caloric value. The only convincing data so far for the energy benefits of ribose is for people with congestive heart failure. The body makes ribose from glucose and though numerous energy drinks contain ribose, the data is lacking for its benefits. The 5-carbon sugars are also used to construct many important cofactors that contribute to energy metabolism so it may be this route that confers some help in energy enhancement.

The 6-carbon glucose is the molecule that serves most living things as the source for biochemical energy. *Fructose* (aka levulose) is transformed to glucose in liver. Simple sugars can pair up with other sugars to make twosomes such as sucrose, lactose, or maltose. Look at the diagrams of glucose and fructose. They are each 6 carbons yet one has the shape of a pentagon and glucose a hexagon. Fructose can be converted in the body to glucose, a time-consuming process. Now look at sucrose that contains both connected. Sucrose is the partnership of glucose and fructose; lactose of mother's milk is GALactose pairing with GLucose.

What's in a Name?

Before we go into how our cells use carbohydrates to make energy, let's look at food labels to see how sugar is disguised. All of these contain glucose or can be converted to it: brown rice syrup, brown sugar, corn sweetener, corn syrup, crystalline fructose, dehydrated cane juice, dextrin, dextrose, evaporated cane juice, fructose, fruit juice concentrate, glucose, high-fructose corn syrup, honey, invert sugar, lactose, maltodextrin, malt syrup, maltose, mannitol maple syrup, molasses,

Nutritional Biochemistry—CONTINUED



raw sugar, rice syrup, sucrose, sugar, sorbitol, sorghum, treacle, and turbinado.

And in the end, these are all sugar! They may come from different sources and be more or less processed but sugar is sugar. Honey and maple syrup have additional minerals and some vitamins but they are essentially metabolized the same way as table sugar.

Energy Storage Molecules — Complex Carbohydrates

Starch, cellulose and glycogen are all long chains of glucose. Starch is an energy storage carbohydrate in plants. Only plants make starch. Animals, including humans do not make starch but construct their own version into a highly branched molecule called glycogen. It is a stored energy source found in liver and muscles. The human body stores enough glycogen to provide enough sugar for 24–36 hours during fasting.

Plants make long strings of hundreds of glucose molecules into starch (digestible) and cellulose (indigestible.) Long chains of sugars are called polysaccharides. The long string of glucose in starch can be used for energy when it's broken into glucose pieces.

Both cellulose and starch are long strands of glucose; the big difference is how the glucose molecules are held together. In cellulose the glucose strand is used for strength in the plant. As starch it is an energy storage molecule. These long chains (also known as polymers) of sugar store energy in its chemical bonds to be used when needed. Most animals, including humans, are unable to break the bonds of cellulose. That's why we call it insoluble fiber. It may be important in minimizing colon cancer and improving elimination.

How Cells Generate Molecular Energy (ATP) — Our Energy Bank

All cells require chemical energy to do their work and keep us alive. At the cellular level, energy comes in the form of a high-energy molecule called ATP (*adenosine triphosphate*), and is crafted in our mitochondria. Carbohydrates are the primary food substrate for energy production.

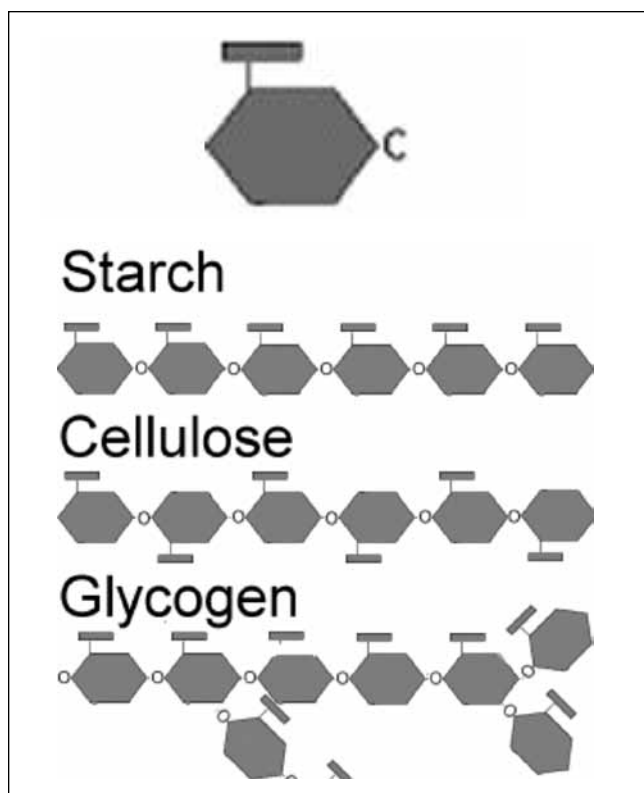
Mitochondria, Another Look

These cellular structures look like creatures from outer space and in fact, millions of years ago they were microscopic organisms that could use oxygen. They merged with organisms to which oxygen was toxic. Evidence for the merger is their lipid composition (found in bacteria) and their own DNA.

The cells that work the hardest requiring the most energy, like heart and muscle, have the most mitochondria, thousands per cell. Red blood cells are the only cell that lacks mitochondria.

The primary chemical source for cellular energy is sugar (glucose, fructose in fruit, table sugar, complex carbohydrates.) *Glucose* is the core molecule for metabolic energy conversion. Fats and proteins are secondary. Through the oxidation or "burning" of sugar or other fuel, energy is produced. The body will burn glucose first and during vigorous exercise use up the glycogen in the muscles and liver. Then it will begin using up the fat for energy.

Nutritional Biochemistry—CONTINUED



These 2 structures on the left are different ways of drawing glucose. Starch, cellulose and glycogen are long chains of glucose. In starch glucose is linked together with the same exact bond. In cellulose, also a long chain except here the glucose molecules are flipped, bound together differently. We have no enzymes to break this bond. Glycogen has links to glucose similar to starch only now the chain has branches.

SOURCE: <http://bioweb.wku.edu/courses/BIOL115/Wyatt/Biochem/Carbos.htm>

When these stores are empty, the body will start digesting proteins for energy. In this case, the proteins are first broken down into their amino acids some of which can be converted into glucose.

Consider right before a marathon, an athlete typically eats lots of carbs like spaghetti to build up the glycogen in the muscles. During the race easily digestible simple sugars will be drunk or eaten to maintain energy once the glycogen is used up (the muscle burn.) After the race, when blood sugar and glycogen is low, the body will burn fats for energy. Hence, calories are used even after the race.

Mitochondria in each cell generate ATP through a multi-step process called electron transport or the respiratory chain. Every cell uses about 1 billion molecules of ATP which are replenished every 2-3 minutes; meaning we need to generate about 2-3 pounds of ATP each day. Some scientists say we need to generate half our body weight of ATP each day. Fortunately much of the breakdown products for "used up" ATP can be recycled back into ATP. This process requires adequate nutritional intake, water, oxygen, B vitamins, Magnesium and Coenzyme Q10. Coenzymes are factors needed to assist an enzyme do its work. Often we just say Co.

A Simple Approach to Understanding Energy Production

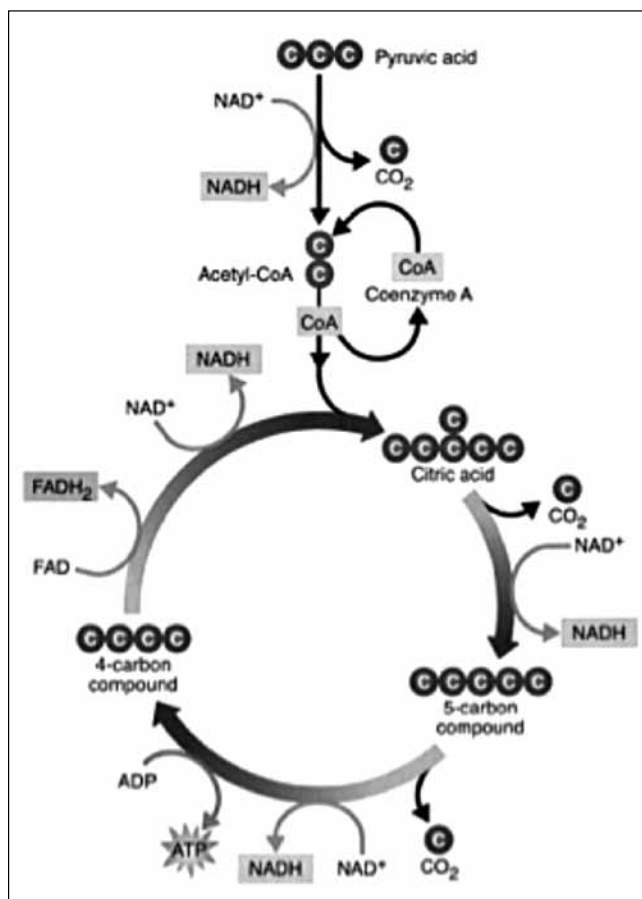
Six-carbon glucose is broken down into two 3-carbon units called pyruvic acid or pyruvate. This occurs without oxygen (anaerobic) in a process called glycolysis — breaking down sugar. This is the same as fermentation only it stops before alcohol production.

If the cycle stops at pyruvate (runs out of oxygen or nutrients) we only get 2 molecules of ATP for every glucose molecule. When it continues on with the burst of oxygen, up to 36 molecules of ATP can be generated from a single molecule of glucose.

In the next oxidative phase, pyruvate loses one carbon into carbon dioxide then pairs with a coenzyme (CoA) to form a high energy molecule acetyl CoA that turns the wheel of Krebs or TCA (tricarboxylic acid) cycle. Acetyl CoA (that bit of glucose left) enters the mitochondria where greater energy production takes place. Through a meandering pathway of passing down electrons — *electron transport and oxidative phosphorylation* — ATP is formed along with water and carbon dioxide (gas.)

Looking at the diagram of the Krebs cycle below, you will see the oxidative phase for energy production starts with pyruvate. Notice the cofactors in the rectangles on the sides, like NADH, FAD, acetyl CoA — these are molecules that contain B vitamins as part of their structures. NAD/NADH

Nutritional Biochemistry—CONTINUED



contain niacin. FAD/FADH contains riboflavin and CoA contains pantothenic acid. So here you can see if someone is depleted in B vitamins why they could be fatigued and energy deficient.

Energy production is actually biological oxidation and involves removing an electron from one molecule and passing it onto the next (electron transport), like a hot potato. Electron transport takes 5 steps to charge up enough energy to make ATP. Sometimes an electron escapes and if not trapped can cause damage to all parts of the cell. Unpaired electrons give rise to potentially dangerous free radicals.

Energy production begins only when glucose or other molecules can get inside the mitochondria. Molecules forming acetyl CoA easily penetrate into the inner sanctum of the mitochondria for further transformation. However, fats need a helping hand in the form of L-carnitine, which when converted

into acetyl-carnitine functions as a transporter into the mitochondria. Carnitine is made from the amino acid lysine. It is found in meats and limited in plants. This process requires Vitamins C, B6, niacin, and iron.

Recipe for Energy Production

Sugar (Glucose) – can come from many sources:

- Sucrose
- Glycogenolysis (breakdown of large molecule glycogen into glucose)
- Gluconeogenesis (glucose made from new sources fatty acids, amino acids)
- Oxygen
- Coenzyme Q10
- Phosphorus, iron and magnesium
- B Vitamins: Thiamin, niacin, pantothenic acid, biotin, riboflavin
- Other Nutrient requirements for mitochondrial health: copper, alpha lipoic acid, and glutathione (GSH.)

Increased Requirements for Energy

- Growth and development, children, pregnant women
- Healing, wounds, tissues, emotions, post-surgical and post-dental procedures
- Illness
- Vigorous exercise
- Stress

Compromises to Energy Production

- Stress
- Too many free radicals
- Mitochondria damage to DNA
- Nutrient-deficient diet or oxygen-deficiency

How does tension and stress diminish cellular energy and induce fatigue?

Nutritional Biochemistry—CONTINUED

A contracted, tense muscle cell produces 2 molecules of ATP for every glucose “burned” (no glucose) compared to a relaxed muscle in an aerobic state that can make 25 molecules of ATP. This is because a contracted muscle moves into an anaerobic stage, no oxygen. Our cells need oxygen to produce abundant energy.

From a practical perspective, if someone is complaining of fatigue it could be because they are highly stressed. When stressed our body is prepared for flight or fight, muscles contract to ready us to run and they use up lots of energy in that preparation. Here's another lifestyle application to try — stress reduction, deep breathing, or meditation — to increase energy production.

Mitochondrial dysfunction may be considered to be part of neurological and muscle diseases including Parkinson's, fibromyalgia and chronic fatigue syndrome. If someone is suffering from muscle pain or fatigue, increasing water intake and considering a magnesium malate supplement may help the mitochondria to recover. If the mitochondria are depleted, muscles break down, pain and fatigue are two consequences. Magnesium malate works in a couple of ways: the magnesium ion helps the muscles relax and is also a requirement for ATP production. Malate is one of the acids in the Krebs cycle so it bypasses the need for sugar for ATP production.

Foods as Source of Energy

Root vegetables, whole grain pasta, and high fiber vegetables are complex carbohydrates that offer an abundance of slowly released glucose molecules. That candy bar chock full of sucrose (glucose-fructose) is rapidly broken into glucose causing a quick burst of elevated blood sugar then energy production. It soon runs out if there's no ready source of glucose.

Honey has the same number of 4 calories per gram as table sugar. Its still sugar just less processed than white table sugar.

What about other sweeteners, how do they contribute to energy?

The non-sucrose/glucose sweeteners taste sweet but most of them are not used by our cells; none can be used for energy production.. They are just discarded but we need to consider what kind of energy is needed to eliminate them. The problem for the body with any of these artificial sweeteners they place a burden on the detoxification system. An occasional soft drink with one of these substances is not a problem for most people but too many can tax the body. Another consideration is that all of them, including stevia, require chemical processing. If the goal is to eat a sustainable whole food diet then avoiding all artificial sweeteners makes good ecological sense for the body and the planet.

Stevia leaves, used first by native peoples in 1,000 AD, is recognized as a “new zero calorie sweetener”, that now has FDA approval as a safe food additive. It's about 250 times sweeter than sugar. But remember that although it is a natural substance, it does go through commercial preparations. Its first commercial use was in Japanese soft drinks about 40 years ago.

Saccharin, an artificial sweetener, was accidentally discovered at Johns Hopkins University about 150 years ago is much sweeter than sugar, with a slightly bitter aftertaste. It is 300 times sweeter than sugar. *Honey bees will not eat saccharin*. Some studies suggest this increases the risk of bladder cancer, though the studies were done on rats.

The pink packets of *Sweet'N Low*® contain a blend of Saccharin, dextrose and cream of tartar (50 years ago.) A reminder about naming chemicals – endings of OSE means it's a sugar. Dextrose is the same as glucose.

Cyclamate, invented about 75 years ago has zero calories and is 30 times sweeter than sugar. It is now banned in the U.S.

The blue packets of *NutraSweet*® and *Equal*® are brand names for *aspartame* sweetener (30 years

Nutritional Biochemistry—CONTINUED

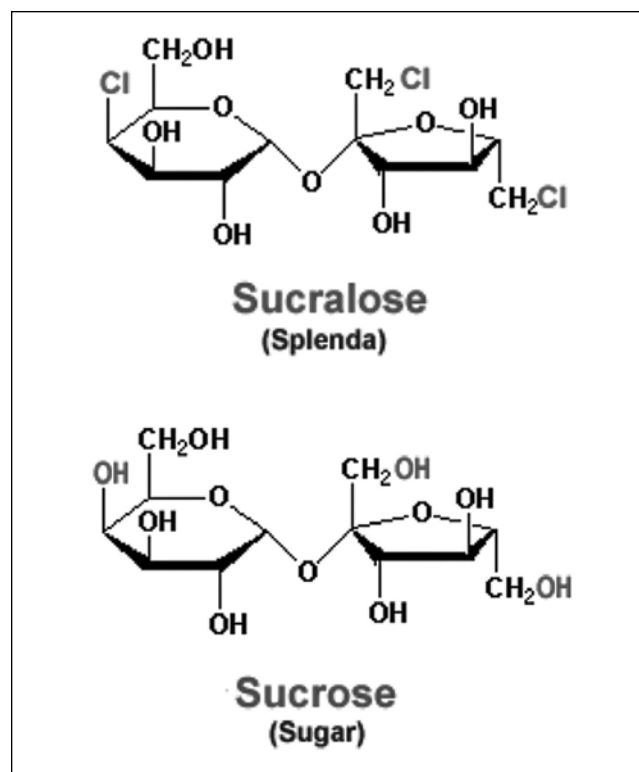
ago.) Aspartame is another zero calorie artificial sweetener 200 times sweeter than sugar. Some people don't like its taste because it reacts with other food flavors. Aspartame is made from amino acids phenylalanine and aspartic acid. Limited toxicity has been reported though people who suffer from PKU, phenylketonuria, should not use aspartame because it releases phenylalanine. (2007 Critical Reviews in Toxicology.)

The yellow packets of *Splenda*®, *Sucralose* were put into use about a decade ago. Sucralose, the current best selling sweetener is approximately 600 times as sweet as sugar. Basically this is a molecule of sucrose that has some of its OH groups (hydroxyl) converted to chloride groups. And though it belongs to a class of chemicals called organochlorides its considered safe in small amounts because it does not accumulate in fat tissue like chlorinated hydrocarbons. It activates the same taste buds as sucrose. If you compare the structures of Sucralose and sucrose, you see that Cl groups have replaced 3 of the OH groups. And though research suggests this is a 'safe' sweetener, unless an individual is a diabetic and must eliminate sugars from the diet, the option is natural sugar not manufactured chemicals.

A Comparison of Sweets and Energy

Glucose raises blood levels quickly and provides rapid bursts of energy when it moves into the cells. It can also be converted into storage molecules of glycogen. Fructose, with the same structural formula as glucose but a different shape, has a much slower effect on blood levels as it must first be converted into glucose in the liver.

The alternative sweeteners provide the sweet taste but not energy sources. And because they don't raise blood glucose levels the tendency can be to eat a lot of artificially sweetened foods since its "low or no calories." Consider what else is in that substance.



SOURCE: <http://www.fooducate.com/blog/quick-food-facts/sugar-synonyms/>

With all the talk about obesity in our children, people blame soft drinks as part of the problem. Since 1984 when Coca Cola and Pepsi switched from sugar to *high fructose corn syrup* (HFCS) in the US, obesity rates in the US have shot up and many fingers have been pointed to HFCS as the culprit, though there are few definitive conclusions. HFCS is a product made from cornstarch and contains a mixture of fructose and glucose in varying proportions. In other countries, sugar is the sweetener of these soft drinks and obesity rates are lower. Though the lifestyle in these countries must also be factored into the problem — lack of exercise, eating fewer meals with the family, consuming fewer fresh fruits and vegetables.

Nutritional Biochemistry—CONTINUED

Personal Energy Management: Holistic Perspectives

What Is Energy Beyond Biochemical Molecules?

Scientists tell us that energy is the ability to create heat, ATP, and burn calories. But there are other immeasurable energies: life force, qi, chi, prana, faith, prayer and love. Energy is also passion, enthusiasm, emotions, and our mood. Other world views of medicine, other than Western, include energy as the key component to health. Different qualities of energy contribute to our vitality and joy for life. Their lack contributes to fatigue and despair, pessimism and ill health.

Energy ABCs

- Awareness and attitudes
- Body cues
- Care and cultivation
- Debts: stress, disease, relationships, overload, fatigue, and burnout
- Enhancers: nourishment, sleep, stillness, movement, exercise, music, relationships, relaxation, community, nature, creativity

Personal Energy Awareness

Understanding one's own energy is a first step in making healthy choices that can secure vitality and help prevent burnout and exhaustion. By journaling you track energy ups and downs, which assists awareness and change. Body cues tell us whether we are under stress. When stressed or tense, the pulse rate often increases as does muscle tension. The temperature of the hands often gets colder and we often hold our breath. Just knowing this helps you monitor where you are moment to moment. It also helps you change behaviors. For instance, you're sitting waiting for an appointment and you notice your hands are icy cold. Remedy, some deep breathing or short walk, visualizing a relaxing place.

Awareness of Physical Body Clues to Link Energy to Emotions and Stress

- Pulse and breath
- Temperature and Tension
- Awareness exercises and body cues: Tuning in
- Physiological markers: Lie detector and bodymind stress
- Daily energy cycles — vitality, mood and tension affect coping with stress

Energy Losses and Stress

As mentioned earlier, stress causes physical tension it also can cause more shallow breathing and rapid heart rate. Tension, whether physical or mental, is a major factor in unnecessary energy loss. Tense muscle cells use energy rapidly and replenish it inefficiently.

The brain does not know the difference between a real stressor and an imagined one. How we cope and think uses energy. You think about a near accident and your cells experience stress – fight or flight. When our energy is used up we don't cope as well with problems. We may lack the resources, mental or physical, to handle the situation. One definition of stress is thinking you don't have the resources to handle the situation.

Energy Replenishment

In reading Bruce Lipton's *Biology of Belief* and other mind-body books, you can see how what you think influences the physiology of your body. If you are in constant anxiety or believe there is a danger (real or imagined), your body 'believes' your mind and initiates the stress response, the rapid use of energy for 'fight or flight.' Your muscles tense and soon you are exhausted without moving a muscle.

- Awareness — body scan, breath, fingers, muscle tension, jaw, shoulders

Nutritional Biochemistry—CONTINUED

- Journal and energy tracking – 3 weeks – monitor lifestyle and energy levels
- Qigong
- Progressive relaxation and meditation
- Creative expression
- Laughter
- Physical exercise

Lifestyle practices to help cultivate energy, in addition to nutritional factors

- Develop your own self-care plan
- Spend quiet time alone
- Do less, say no, and BE
- Learn mindfulness meditation or other meditation practice
- Reconnect with a spiritual source
- Recharge your batteries daily. Walk
- Hold one focused connected and meaningful conversation each day
- Play, pleasure, laugh
- Value and cherish yourself

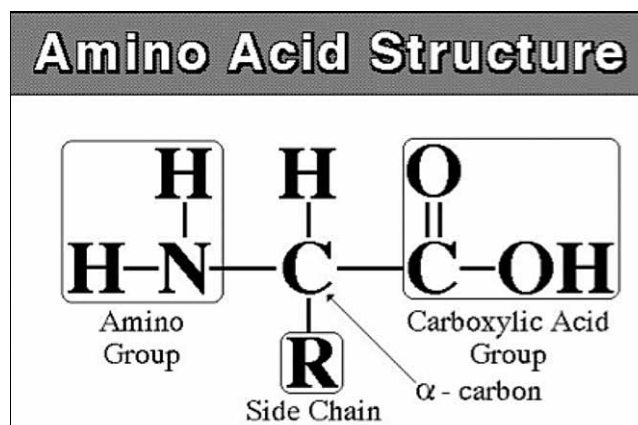
Chemistry of Structure, Support and Protection

We've looked at the basics of chemistry, our cells and energy, now we take a look at the controllers of all of the processes.

Basic Structures for Protein Building

We get protein from meat, fish, eggs, dairy, veggies, beans, nuts, whole grains. and algae. Digestion breaks down food proteins into their building blocks- amino acids – which are then used to produce the proteins we need in the body, like muscle, blood, hair, some hormones, skin, enzymes, and thousands more.

Proteins, like starch molecules, are large long chains (polymers.) Unlike starch, which is built



from only one kind of molecule, glucose, proteins are composed of about 20 different amino acids. They can be hundreds of amino acids long and may contain several chains.

The shape of the protein influences how it will function. You can consider proteins as the most "active" molecule in your body. Protein molecules are enzymes, immune antibodies, antigens, regulators, some hormones and cell receptors.

It is the unique structure of amino acids that make proteins so versatile. Amino acids contain both an acid group ($-\text{COOH}$) and a basic amino group (NH_2 .) They all contain nitrogen unlike fatty acids that have only the acid group. Our bodies can make *non-essential* amino acids while we must obtain the *essential* amino acids from food sources. It is the requirement for essential amino acids that is particularly relevant to people choosing vegetarian or vegan diets.

Amino Acid Overview

The primary structure of an amino acid:

- The "R" group or side chain is what distinguishes one amino acid from another. It is the placeholder for a specific chemical portion of a molecule. In the amino acid structure, all but the R group could be considered "generic" – every amino acid has that structure.

Nutritional Biochemistry—CONTINUED

Examples of Amino Acid Types

The side chain or R group classifies the amino acid as:

- Aliphatic or branched
- Aromatic (cyclic compound)
- Basic (positively charged — 2 or more N groups)
- Acidic (negatively charged — 2 COOH groups)
- Polar (contains additional OH, SH)

What's Essential?

The eight amino acids listed below are generally regarded as essential. You can see that these are the branched chain and the more complex structures. They are obtained from meat, dairy, eggs — animal foods. Most plant foods lack one or more of the essential amino acids. In addition to their incorporation into proteins, essential amino acids are precursors for other compounds

1. Phenylalanine is used to make tyrosine
2. Valine
3. Threonine is used to make glycine and serine
4. Tryptophan is used to make serotonin, melatonin and niacin
5. Isoleucine can be used by the krebs cycle
6. Methionine is used to make cysteine, carnitine, taurine, lecithin, and phospholipids
7. Leucine
8. Lysine is used to make acetyl CoA

Some amino acids are essential only in infants and growing children: cysteine (or sulfur-containing amino acids), tyrosine (or aromatic amino acids), histidine and arginine. The body does not synthesize essential amino acids. In addition, arginine, cysteine, glycine, glutamine, histidine, proline, serine and tyrosine are considered conditionally essential, meaning they are not usually required in the diet except to specific populations that can not synthesize it in adequate amounts.

If the diet emphasizes proteins, like vegetarian, that lack the essential amino acids, a person can get into grave danger since normal functional proteins can not be made. However, combining plant foods make a whole protein possible. Here's a list of common vegetarian protein sources and the essential amino acid that is limited in it.

PROTEIN SOURCE	LIMITING AMINO ACID
Wheat	Lysine
Rice	Lysine
Legumes	Tryptophan or methionine (or cysteine)
Maize	Lysine and tryptophan

Plants that do contain complete proteins (all essential amino acids) are soybeans and quinoa. Unlike wheat and rice, the seed quinoa, often used as a grain, contains a balanced array of amino acids including lysine. Its about 14% protein. Soy, a legume, on the other hand, also contains a complete protein but has additional properties that must be considered. It contains a high concentration of phytoestrogens which influences cell estrogen receptors. Studies from Asian countries in which soybeans are a major protein source show lower incidence of heart disease sex hormone cancers (breast, ovarian, and prostate) linked to the lifelong consumption of soy foods. Taking soy supplements is contraindicated in women with breast cancer.

Amino acids have several functions. They all contribute to protein structure. Some also act as neurotransmitters (regulators of brain function) such as glutamine and glutamic acid; others are precursors to hormones (tyrosine to adrenalin; tryptophan to serotonin.) Some amino acids can be converted to glucose and used for energy production.

The most abundant amino acid in our blood is glutamine. Rapidly dividing cells like the GI tract, blood cells and hair follicles all need glutamine. It can cross the blood-brain barrier and can be used

Nutritional Biochemistry—CONTINUED

as an energy source for the brain if glucose is low. It's also a primary energy source for the GI tract when the gut needs rebuilding. Raw spinach, cabbage and parsley are good plant sources. Meat, fish, yogurt and eggs are also good foods. Cooking destroys some of it.

Amino Acids to Proteins: The Peptide Bond

The amino group of one amino acid links to the acid group of another. In the process, water is released. The bond formed is called a peptide bond. Several amino acids linked together are called peptides or polypeptides. Polypeptides can contain up to 49 amino acids; 50 or more amino acids in the chain are now called a protein. You can think of a peptide as a small protein.

Protein Synthesis

For our bodies to produce a protein, it needs the directions from our genes to know the sequence of the amino acids in the long chain. DNA in our genes contains the code that dictates which amino acid is first in the chain, second, etc. The nucleus of the cell contains the genes for all the proteins in the body, except those in the mitochondria. The human genome project discovered that there are about human 30,000 genes and until recently it was believed that our choices could not influence them.

Nutrigenomics is an exciting new field of study of how foods affect our genes. This has incredible potential for preventing or treating certain chronic diseases like cancer. Dr. Dean Ornish is a cardiologist who has devoted his life to lifestyle intervention for decreasing or reversing illness in people with heart disease and cancer. Lifestyle medicine includes nutrition, stress reduction, meditation, exercise, and group support. Ornish's recent study of men diagnosed with prostate cancer showed that prostate cancer gene expression and PSA (indicator of prostate inflammation or cancer) could be diminished by eating low-fat, whole

foods, plant-based diet and following the lifestyle recommendations for three months. This field is in its infancy and shows great promise.

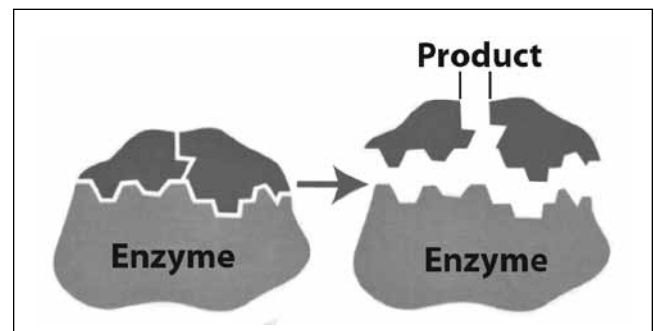
Protein Functions

Enzymes

The human body has about 100,000 different proteins and at least 5,000 enzymes. All enzymes are proteins. Enzymes catalyze chemical reactions lowering the amount of energy needed to make the reaction possible. In the human body, most enzymes work best at body temperature and around pH 7.2. On the other hand, most digestive enzymes operate under acid conditions, as low as pH 2. Other enzymes (and proteins) are destroyed at low pH therefore when taking oral enzymes, you must be aware if the enzyme is active or destroyed by acid. They must be enteric-coated to protect them from the acid. Stomach acid will denature (break up) most proteins and make them lose their function. Proteins are broken down into their amino acids.

Naming Enzymes

A protein with a name that ends in *-ase* is an enzyme, for example lipase, amylase, and protease. Proteins that end in *-inogen* tells us that it has the potential to become an enzyme provided it's acted upon by another enzyme. Examples: pepsinogen becomes pepsin; trypsinogen becomes trypsin. Most of these break down other proteins.



SOURCE: <http://www.carefreeenzymes.com/sitebuildercontent/sitebuilderpictures/EnzymeExample.jpg>

Nutritional Biochemistry—CONTINUED

How Enzymes Work

You can think of enzymes and what they work upon (the substrate) as puzzle pieces. They must fit each other exactly for the reaction to take place. Vitamins and other cofactors like minerals aid in helping make the correct fit. The same nutrients that are needed to produce any protein are needed to make enzymes. What may differ is that some enzymes may have a mineral like iron or copper as part of its structure.

For example, the enzyme amylase will have starch (long chain of glucose) as its substrate; the products will be smaller units of glucose such as maltose (2 glucose molecules) and glucose. The enzyme is specific for its substrate. Using your experience chewing the cracker you detected amylase at work.

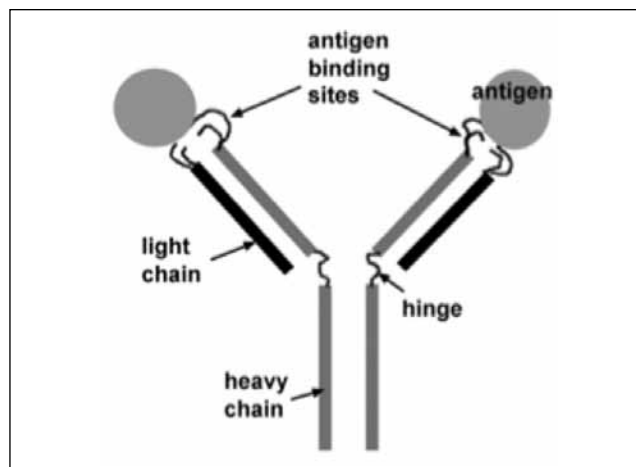
Other important enzymes for this discussion include the enzymes (bromelain, papain) that diminish inflammation. The source of bromelain is pineapple and papain comes from papaya.

The raw food advocates claim that cooking destroys the beneficial enzymes in food. That is true. However, digestion also destroys the enzymes and proteins in raw or cooked food. Our bodies make their own enzymes from amino acids they derive from food proteins, cooked or raw.

Immune Proteins – Antibodies

The specific molecules made by the immune cells that react with antigens are called antibodies or immunoglobulins. All of these are proteins. There are different classes of immunoglobulins that vary in size and where they work. The major immunoglobulin in our blood is IgG, in our saliva and gut, IgA. The basic structure of an immunoglobulin consists of two chains and similar to enzymes there is an exact fit between antibody and antigen.

The immune cells in response to an invading microorganism produce other immune proteins such as cytokines, interferons, and interleukins.



SOURCE: <http://www.cas.vanderbilt.edu/bsci111b/immunology/antibody.gif>

Cellular Protection

When there is a microbial attack, our cells respond with numerous reactions. The first is their ability to recognize a foreign agent. This happens through cell receptors that activate further responses. Immune cells produce chemicals that will directly kill the organisms. One family of chemicals is called free radicals.

Free Radicals

Free radicals are highly unstable since they have an unpaired free electron that makes them energetically out of balance. Free radicals get balanced by stealing an electron from another molecule. This process is called oxidation and turns the second molecule into a free radical.... can be a chain reaction, one stealing electron from another.

Foods that contain nutrients that quench free radicals are fruits and vegetables. In fact, numerous research studies indicate that people who eat a diet rich in fruits and vegetables have a lower incidence of many chronic illnesses associated with excess free radicals especially heart disease.

Free radicals are both good and bad. Their beneficial functions include microbial killing, activating genes, liver detoxification, and blood vessel relaxation. Their negative effects include damag-

Nutritional Biochemistry—

ing other molecules and tissues. If free radicals damage DNA it increases the likelihood for gene mutations. They can damage the eye and increase the propensity for macular degeneration. They can oxidize LDL-cholesterol increasing the likelihood for coronary artery blockage. They can also damage the mitochondria, which affects energy production.

Where Do Free Radicals Come From?

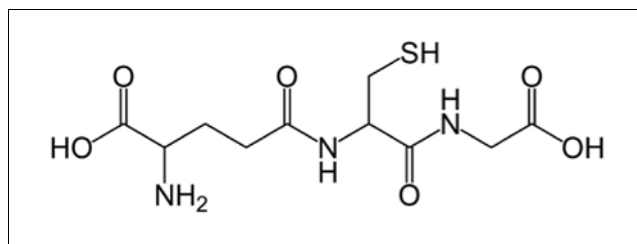
Our bodies make them during energy production, infection, and inflammatory responses. The environment also is a source in the UV light from the sun, air pollution, cigarette smoke, pesticides and car exhaust.

How Are We Protected?

In the wisdom of the body that makes free radicals, it also makes free radical scavengers, molecules that eliminate free radicals. These scavengers are called antioxidants. Free radicals are oxidants and antioxidants diminish or eliminate their damaging effects.

Many of our enzymes have antioxidant activity such as superoxide dismutase. Superoxide is a reactive oxidant; the dismutase converts it to a non-reactive molecule. Some proteins, in addition to their other functions, many also have antioxidant activity. Melatonin is an example.

The most important antioxidant inside our cells is glutathione, abbreviated as GSH. GSH is a tripeptide made up of three amino acids – glycine, glutamic acid, and cysteine. One measurement of cell health is the level of GSH. The lower the level, the less healthy. This structure of GSH is another way of drawing chemical structures. Each bend represents a Carbon atom. The active part of the molecule **as an antioxidant** is the sulfur SH group. When GSH acts as an antioxidant it becomes inactive as an antioxidant so it must be recycled back to GSH. This is a cyclic process. Basically, once an antioxidant does its work, it's lost its ability to be an antioxidant until regenerated.



Glutathione (GSH)

Antioxidant Activity

When an antioxidant does its job, it becomes a free radical so it's necessary to have a process that continually regenerates antioxidant activity. In other words, it's used up until regenerated by another antioxidant.

In addition to the antioxidants our bodies make, like GSH and alpha lipoic acid, our diet contributes hundreds of different molecules that function as antioxidants. Many are in produce, spices and those highly colored fruits and vegetables. All the pigments, like the purple skin of a grape, are antioxidants. They protect the fruit or vegetable from oxidation and damage from the sun and air.

Dr. Les Packer at UC Berkeley described an 'antioxidant network' which includes GSH, lipoic acid, coenzyme Q10, Vitamins C and E. The first three we can produce though as we age we may make less. These molecules can regenerate each other. Scientists consider lipoic acid as one of the most important to regenerate GSH. Some health professionals recommend oral GSH to help protect the cells, however most of it will be broken down by the digestive tract into the 3 amino acids which go into the pool for making any peptide or protein. Most studies recommend taking alpha lipoic acid as the best way to generate GSH. The water soluble antioxidants vitamin C and GSH protects the cytoplasm and DNA. Fat soluble antioxidants like Vitamin E and CoQ10 protect the cell membranes and unsaturated fats. Lipoic acid is both fat and water soluble and can act anywhere in the cell.

Nutritional Biochemistry—CONTINUED

Other important molecules to the antioxidant system are selenium and zinc salts that activate antioxidant enzymes.

Who Needs to Take Antioxidants?

Healthy individuals who eat a whole food diet with lots of fresh fruits and vegetables don't really need to take supplements. However when you begin to understand if you are exposed to more dangerous free radicals – chronic infections like HIV, marathon athletes (UV, air pollutants), or chronic inflammation (diabetes, heart disease), taking antioxidant supplements may be something to consider. The data is conflicting on whether antioxidant supplements can protect us from cancer and heart disease. In addition, it is controversial whether people with cancer undergoing chemotherapy or radiation should take antioxidant supplements. Some data suggest they prevent the treatment from working; other data report that they help. This should always be discussed with the nutrition consultant and oncologist.

The Inflammatory Response

Inflammation is a basic immune response to damaged tissue or infection. Factors that can trigger inflammation include pathogens, allergens, auto-

immune diseases, injury, stress (physical and emotional), hormonal imbalance and free radicals.

The more we understand the biology of disease the more inflammation is implicated as part of the process. Whereas we once saw heart disease as a result of excess fat intake, we now know that inflamed blood vessels are the first step to coronary artery disease. The inflamed tissue makes a welcome place for deposits of plaque. Illnesses that have been shown to have inflammation as a factor include diabetes, heart disease, food sensitivities and Alzheimer's. What this means to the nutritionist and the general population, that knowing anti-inflammatory strategies, we may prevent or delay these illnesses.

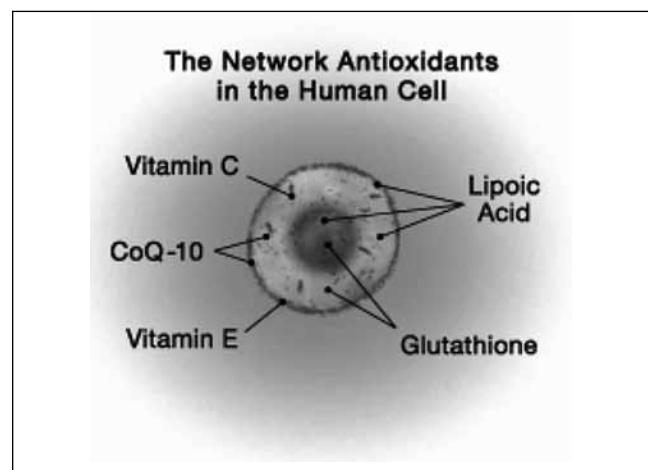
Histamine is the primary inflammatory molecule that our cells release which initiates the whole process. Therefore, anyone suffering from inflammation, chronic illness, infection, food allergies should avoid foods that contain histamine – cheeses, fermented soy foods, sauerkraut, wine, vinegar, eggplant and spinach.

Protective Foods

Eating For Health™ and other plant-based whole food dietary regimens can protect against excessive inflammation. The Mediterranean diet rich in fresh foods and olive oil (plus the lifestyle) has been shown to lower the risk of heart disease and even Alzheimer's. Foods considered important to good health include fatty fish high in omega 3 fats, avocados, flax, and the colorful rainbow of foods that protect against inflammation.

In addition to foods that are protective, many herbs and spices are potent antioxidants and anti-inflammatories. These include Curcumin (turmeric), garlic, and onions (quercetin.) Bioflavonoids are plant pigments that function as antioxidants and anti-inflammatory.

Bioflavonoids are divided into different categories. Anthocyanidins are the purple and dark-red pig-



SOURCE: <http://www.antioxidants-for-health-and-longevity.com/images/human-cell-network-ant.jpg>

Nutritional Biochemistry—CONTINUED

ments found in blueberries, blackberries, cranberries, red and purple grapes, grape juice, and red wine. The basic backbone of this family of chemicals.

Flavanols, such as catechin and epicatechin, are in cocoa, green tea, red wine, apples, and berries. Flavanones are found in citrus fruit, in the white material and pulp.

Isoflavones are in soy products, as well as legumes. Bioflavonoids should be viewed as a group of beneficial phytochemicals, which are most effective when taken from a variety of organic sources and needed in small amounts. As long as you eat a healthy diet, rich in berries, citrus, soy, and tea, there is no need to take bioflavonoid supplements.

We are a biochemical wonder when you consider that you can eat a big salad, pasta and some chicken and all that delicious food is broken down into invisible building blocks for life. Our cells know what to do and depend upon us to feed them with the freshest most nutritious ingredients. When you think about the phrase — you are what you eat — you are. Choose wisely and enjoy.

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Notes

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